Orbital Debris Penetration Resistance of Reusable Launch Vehicles

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A preliminary set of orbital debris impact simulation tests has recently been completed in support of the NASA Reusable Launch Vehicle program. The results of these tests were used to estimate the probability of no penetration of a typical launch vehicle. Several different thermal protection system and structure design specimens were tested, with the objective of determining the most promising combination to resist penetration by meteoroids and orbital debris in low-Earth orbit.

During the 1995 fiscal year, MSFC performed hypervelocity impact tests on 63 thermal protection system/ structure designs in the Debris Impact Simulation Facility operated by the Space Environmental Effects Branch within the Materials and Processes Laboratory. Test results, analyzed by the Structural Development Branch of the Structures and Dynamics Laboratory, were used to determine the penetration probability of a typical reusable launch vehicle for its expected lifetime over a baselined set of missions. Results indicated "penetration" or "no penetration" for various aluminum spherical particle diameters, all at approximately 6-kilometers-per-second impact velocity. By extrapolating the data to represent the higher velocities expected on-orbit and particles of more dense material, a "critical" penetrating particle was estimated for the average expected impact velocity. Next, using the NASA meteoroid and orbital debris environment models for low-Earth orbit, an estimation of "critical" particle impact probability was estimated. In addition, an equation to predict the penetration resistance of thermal protection/ structural systems has been developed. Further tests and analyses are expected to be performed in the 1996 fiscal year.

Accomplishments gained contribute significantly to NASA and industry capabilities for future evaluation of thermal protection systems and structures for use on low-Earth orbit spacecraft. Before this task was completed, no known equations existed that could predict the penetration resistance of such complicated systems. The commercial potential for this effort is immediate and significant. Private industry is already using the data in the preliminary designs of reusable launch vehicles for commercial use in the next 10 years, including current work to optimize system weight. Other potential uses include space station crew return vehicles, space shuttle design improvements, and other reusable vehicles that must return to Earth through the harsh reentry environment.

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